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Phytochemical and Proximate Contents of Some Medicinal Plants Used in Herbal Medicine under various drying methods

Ebabhi, A.M.[1*], Kanife, U.C[2]. and Asekunowo, A.K[3].

[1]Biology Unit, Distance Learning Institute, University of Lagos, Lagos, Nigeria
[*]Corresponding email: aebabhi@unilag.edu.ng
[2]Department of Biological Science, Yaba College of Technology, PMB 2011, Yaba, Lagos, Nigeria
uchenna.kanife@yabatech.edu.ng

[3]Department of Chemistry, Faculty of Science, University of Lagos, Nigeria. aasekunowo@unilag.edu.ng

Abstract

Drying is one of the most antique processes to preserve quality of aromatic and medicinal plants. The aim of the study was to evaluate the phytochemical and proximate contents of Annona muricata, Azadirachta indica, Citrus latifolia and Cymbopogon citratus leaves dried variously in the shade, sun and oven (40 ! and 100 !) using standard analytical methods. The results revealed that the phytochemical and proximate contents vary from plant to plant and amongst the drying methods. The result of the qualitative phytochemical screening indicated the presence of alkaloids, saponin, flavonoids, tannin, phenol, and terpenoid in all the plant samples. Flavonoids was only observed absent in the 100 °C oven-dried leaves samples of C. latifolia and Cymbopogon citratus while anthraquinone was only present in the fresh and shade-dried samples of C. latifolia and C. citratus. In the quantitative phytochemical screening, the quantity of alkaloid was lowest in the fresh samples of all the analysed plants while the highest values for saponin was observed in the 40 °C oven dried samples in three quarter of the sampled plants. The result also showed the presence of proximate contents (carbohydrate, crude protein, lipid, moisture, ash, crude fibre), in the sampled leaves dried under the various drying methods. Shade-dried samples showed the highest values for carbohydrate and total ash content while the fresh samples showed highest values for crude lipid and moisture contents. Drying of medicinal plants can affect the proximate and phytochemical compositions which can alter the pharmacological quality of the plants.

Keywords: Drying methods, Medicinal plants, Phytochemicals, Proximate content

Introduction

As defined by the World Health Organisation (WHO, 2007), a medicinal plant is any plant which in one or more of its organs contains substances that can be used for therapeutic purposes or which are precursors for the synthesis of useful drugs in pharmacy. Finding from Edoga *et al.* (2005), Afolabi and Afolabi (2013) and Kutama *et al.* (2018) posited that medicinal plants do contain some organic compounds which can provide definite physiological actions on the human body and these bioactive substances include alkaloids, carbohydrates, flavonoids, saponins, steroids, tannins, and terpenoids. These plants are utilized industrially in present day prescription and pharmacology (Offor, 2014). Freeman and Beattie (2008) and Loi *et al.* (2020) also submitted that bioactive compounds in plants form aspects of a plant's component against diseases while Calderón-Oliver and Ponce-Alquicira (2018) agreed that these bioactive compounds contribute to the colour, flavour and smell of plants.

Since the dawn of medicine, phytochemicals obtained from medicinal plants, have been used to help mankind sustain her health (Veeresham, 2012; Sofowora *et al.,* 2013; Boy *et al.,* 2018). The essence of these phytochemicals in agriculture and medicine also stimulates significant scientific interest in the biological activities of these substances (Moghadamtousi *et al.*, 2013; Mendoza and Silva, 2018).

However, the processes of harvest, preservation, extraction and identification of these phytochemical compounds from plants give rise to degradation of most of these phytochemicals before use. Chemical changes are the most important in the post-harvest of medicinal plants and can be influenced by drying. Rocha *et al.* (2011) posited that drying is the most common way to preserve the quality of aromatic and medicinal plants. The *drying* process *affects* the *quality* of the *herbal* preparation by altering its chemical composition, active principal content and bioactivity as submitted by Rocha *et al.* (2011) and Poós and Varju (2017). During the drying process, it is well known that numerous physical, chemical and nutritional changes occur in plants which can affect quality attributes. Annamalai *et al.* (2011) stated that the drying process may affect antioxidant capacity, nutritional and physical quality of the herbs while Turek and Stintzing (2013) posited that it may cause the volatile profile of essential oil to change due to the formation of secondary aroma compounds such as alcohols, aldehyde, ketones and peroxides. According to Muller and Heindl (2006), medicinal plants can be dried in a number of ways: in the open air (shaded from direct sunlight); placed in thin layers on drying frames, wire-screened rooms or buildings; by direct sunlight; in drying ovens/rooms and solar dryers; by indirect fire; microwave; or infrared devices. Drying is an effective method that increases the shelf life of the final product of some plants by slowing the growth of microorganisms and preventing certain biochemical reactions that may alter their characteristics. Orphanides *et al.* (2016), posited that most fresh herbs have high moisture content therefore, they are processed by drying to generate shelf-stable products. The most popular method of drying is convective drying; however, increase in the temperature usually results in quality decrease of the dried herbs (Diaz-Maroto *et al.,* 2002). This study was set out to evaluate the phytochemical and proximate contents of *Annona muricata, Azadirachta indica, Citrus latifolia* and *Cymbopogon citratus* leaves commonly used in herbal medicine under various drying methods.

MATERIALS AND METHODS

Plant samples

Fresh and healthy leaf samples of *Annona muricata* Vell, *Azadirachta indica* A. Juss, *Citrus latifolia* Tanaka and *Cymbopogon citratus* Stapf, were collected within the premises of the University of Lagos, Nigeria. The leaves were transported to the laboratory in Ziploc bags and authenticated

by plant taxonomist in the Department of Botany, University of Lagos. Voucher specimens were deposited at the Lagos University Herbarium. The leaves from each plant were plucked from the stems and divided into five groups of 2 kg each. Each group was thoroughly washed under running water to remove debris and blotted to remove excess water. The leaves of each plant labelled A, B, C and D were then set out for drying while the fifth part labelled E (fresh samples) for each plant were not dried but analyzed as the control samples.

Procedure for drying

Based on traditional drying procedures four methods which were oven-drying (40 ! and 100 !), sun-drying and shade drying were used for drying the leaf samples. The group A labelled samples were dried in thermostatic oven for 4 h at low heat of 40 ! while the group B samples were oven-dried at high temperature of 100 ! for 2 h. The leaves labelled C were sun-dried in trays at specific times (sun rise to sun set) at 96 h intervals while the group labelled D were shade-dried for 144 h under natural airflow and ambient temperature. Fresh leaf samples (labelled E) of the plants served as the control. Each sample was pulverized into fine particles using electric blender.

Phytochemical screening

Phytochemical screening of the plant samples was analyzed using standard protocols as described by Ukoha *et al*. (2011), Dhani, (2012), Hossain *et al*. (2013) and Auwal *et al*. (2014).

Proximate Analysis

Proximate analysis was carried out according to the procedure of Association of Official Analytical Chemists (AOAC, 2012) for moisture, ash, crude fibre and crude protein content. According to the procedures described by Thiex (2009) and Maisarah *et al.* (2014), the carbohydrate content was calculated by subtracting the sum of the percentage of the ash, crude lipid, crude protein, crude fibre and moisture from 100 %.

Statistical analysis

Results from phytochemical and proximate analyses were expressed as mean± standard deviation and statistical analysis was performed using SPSS statistical package. A least significant difference at 5% probability was considered significant.

RESULTS

Qualitative phytochemical analysis of plant samples under different drying conditions

Tables 1a-d shows the qualitative phytochemical analysis of the leaves of *Annona muricata*, *Azadirachta indica, Citrus latifolia* and *Cymbopogon citratus.* It was observed that in the drying methods used (oven-drying, sun-drying and shade drying) alkaloids, saponin, flavonoids, tannin, phenol, and terpenoid were present in all the plant samples at different drying methods. Anthraquinone was present in the shade-dried and fresh (control) samples of *C. latifolia* and *C. citratus* while it was only observed in the fresh sample of *A. indica*. Anthraquinone and steroid were not detected in all samples of *A. indica* but steroid was detected in the shade dried and fresh samples of the *C. citratus* and only in the fresh samples of *Citrus latifolia.* Tannin was only observed present in the fresh sample of *C. latifolia* while it was not detected only in the shade dried sample of *A. muricata*. Flavonoid was noticed in the fresh samples of all the plants' leaves and in the samples of all drying methods used except from the 100 °C oven-dried samples of *C. latifolia* and *Cymbopogon citratus.*

Tables 1a-d: Qualitative phytochemical compositions of plant samples at different drying methods

Table 1a: *Cymbopogon citratus* (Lemon grass)

Phytochemicals	Sun	40 °C	100 °C	Shade	Fresh samples
Alkaloid	-	+	+	-	+
Saponin	+	+	+	-	+
Flavonoid	+	+	-	+	+
Anthraquinone	-	-	-	+	+
Tannin	+	+	+	+	+
Steroid	-	-	-	+	+
Phenol	+	+	+	+	+
Terpenoids	+	+	+	+	+

Table 1b: *Citrus latifolia* (Lime)

Phytochemicals	Sun	40 °C	100 °C	Shade	Fresh samples
Alkaloid	+	+	-	+	+
Saponin	+	+	+	+	+
Flavonoid	+	+	-	+	+
Anthraquinone	-	-	-	+	+
Tannin	+	+	-	-	+
Steroid	-	-	-	-	+
Phenol	-	-	-	+	+
Terpenoids	+	+	+	+	+

Table 1c: *Annona muricata* (Sour-sop)

Phytochemicals	Sun	40 °C	100 °C	Shade	Fresh sample
Alkaloids	+	+	+	+	+
Saponin	+	+	+	+	+
Flavonoids	+	+	+	+	+
Anthraquinone	-	-	-	-	-
Tannin	+	+	+	-	+
Steroid	-	-	-	-	-
Phenol	+	+	+	+	+
Terpenoids	+	+	+	+	+

Table 1d: *Azadirachta indica* (*Neem)*

Phytochemicals	Sun	40^0C	100 °C	Shade	Fresh sample
Alkaloids	+	+	+	+	+
Saponin	-	-	+	+	+
Flavonoids	+	+	+	+	+
Anthraquinone	-	-	-	-	+
Tannin	+	+	+	+	+
Steroid	+	+	+	+	+
Phenol	+	+	+	+	+
Terpenoids	+	+	+	+	+

'-'connotes absence of the phytochemical while '+'connotes presence

Quantitative phytochemical analysis of plant samples under different drying methods

In the results of the quantitative contents analysis, the quantities of the phytochemicals tested were observed to vary along the different drying methods used as well as from one plant species to the other. The quantity of alkaloids was observed to be lowest in the fresh samples of all the leaves of the sampled plants while there were also variations in the various drying methods used. It was highest in the sun-dried samples of *Annona muricata* and *Citrus latifolia* respectively at 24.23±0.02 mg/100g and 13.97±0.02 mg/100g while it was highest in the shade dried samples of *Azadirachta indica* at 59.23±3.35 mg/100g and also highest in the 40 °C dried samples of *Cymbopogon citratus* at 27.15±0.02 mg/100g.

In the saponin analysis, the highest values for most of the plant samples were obtained from the samples oven dried at 40 °C, it was 27.84±0.02 mg/100g for *A. muricata,* 36.12±0.02 in *C. latifolia* and 31.65±0.01 in *C. citratus.* For *A. indica* the highest value of saponin was obtained from the 100 °C oven dried sample at 27.56±0.15 mg/100g while it was not detected in the 40 °C oven-dried and sundried samples.

The quantities of tannin and phenol contents were noticed to be highest in the fresh samples of all the plant leaves sampled compared to the other drying methods used. There were deceases in quantities in the various drying methods. It was observed that drying method had no influence on the flavonoid contents of the samples. However, flavonoid contents varied with respect to plant species as expected. In *A. muricata,* the highest quantity of 39.24±1.10 mg/100g was obtained from the shade dried sample while for *C. latifolia* and *Cymbopogon citratus,* the highest quantities were obtained from the sun-dried samples respectively at 26.05±0.02 and 23.24±0.01 mg/100g. It was highest for *A. indica* at 32.67±1.09 mg/100g in the 40 °C oven-dried sample. The results for the quantitative phytochemical content analysis are presented in Figures 2a-d.

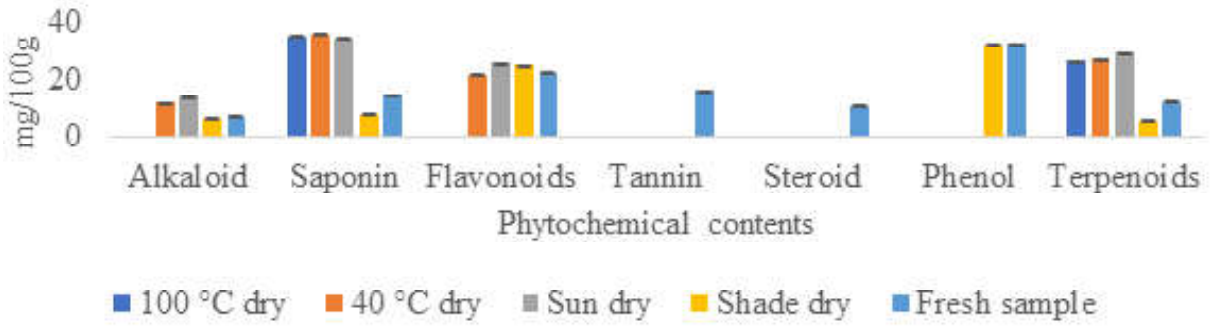

Figure 2a: Phytochemical components of *Citrus latifolia* at difference drying methods

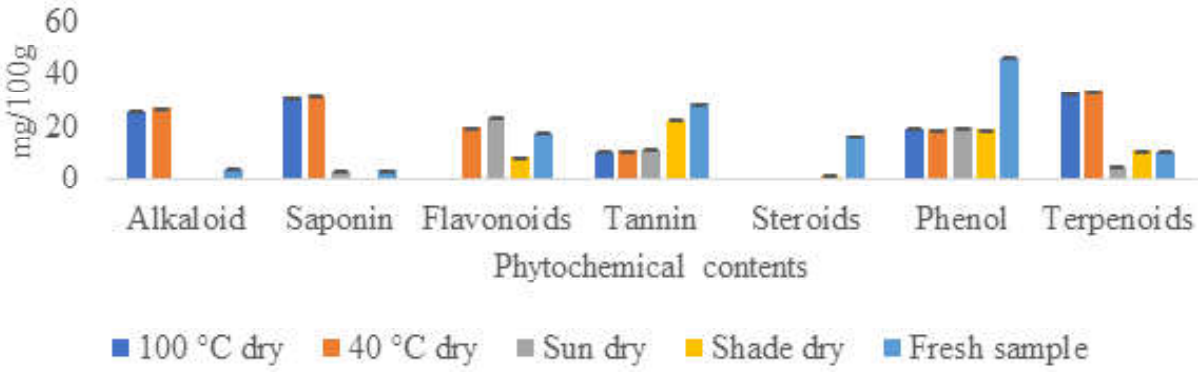

Figure 2b: Phytochemical components of *Cymbopogon citratus* at difference drying methods

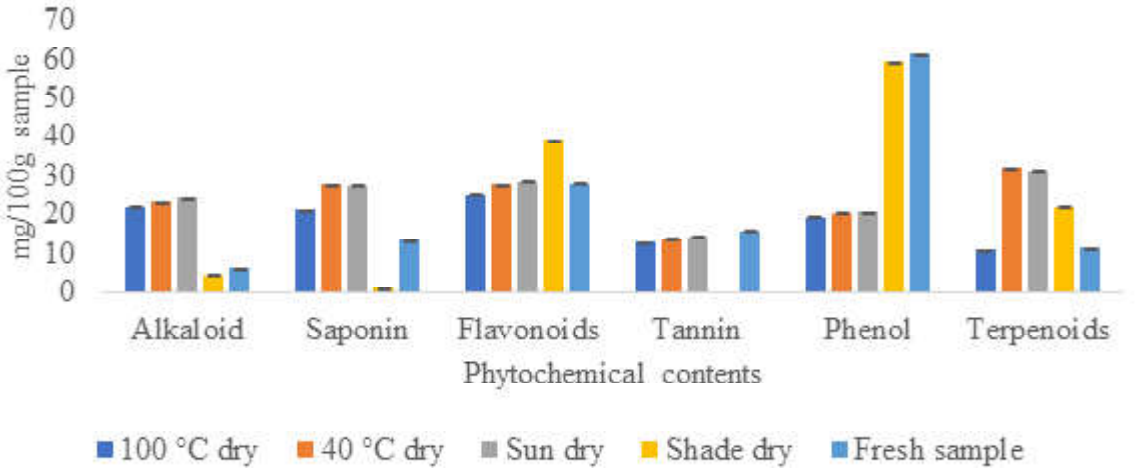

Figure 2c: Phytochemical components of *Annona muricata* at difference drying methods

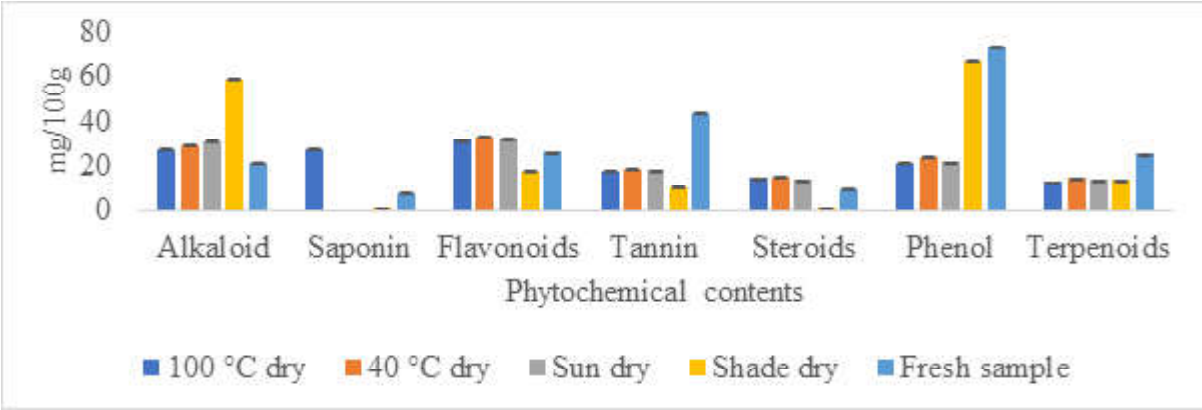

Figure 2d: Phytochemical components of *Azadirachta indica* at difference drying methods

Proximate composition of sampled plants under different drying conditions

The results of the proximate composition for the sampled leaves of *Annona muricata, Azadirachta indica, Citrus latifolia* and *Cymbopogon citratus* are displayed in Tables 3a-d. It was observed in the proximate analysis of *Citrus latifolia* that the shade-dried sample had the highest value of carbohydrate at 68.74±0.25 % while the fresh sample (control) showed the lowest value at 28.08±0.06 %. There was no significant difference in the values of crude protein in the fresh sample (4.21±0.02 %) and shade-dried sample (4.42±0.04%) in relation to the other drying methods put respectively at 15.72±0.03 (dried at 40 °C), 19.15±0.02 % (dried at 100 °C) and 16.90±0.15 % (sun-dried). The crude lipid and moisture content of the control sample (fresh sample) and total ash contents of the shade-dried sample were relatively high compared to the samples in the sun-dried and oven-dried. This is as shown in Table 3a.

Proximate composition of *Cymbopogon citratus* in this study showed that carbohydrate content in the shade-dried condition had the highest value at 57.84±0.12 % while the fresh sample had the lowest value of 23.20±0.04 %. Crude protein content was highest (17.32±0.15%) in the 40 °C oven dried sample showing a significant difference with the fresh sample which revealed a value of 5.09±0.02 %. Crude lipid content was highest in the fresh sample (37.82±0.03%) showing a significant difference from the values of the other drying methods. It was also observed that the value of moisture content in the fresh sample is relatively high in comparison with the samples dried under the other various methods. Crude fibre was highest at 30.58±0.02 % in the 40 °C oven-dried sample and lowest at 7.84±0.07 % in the control sample. The result of the proximate composition of *C. citratus* is shown in Table 3b.

There was no significant difference amongst the values of carbohydrate, crude lipid, crude protein, crude lipid, crude fibre and moisture contents of the *Annona muricata* samples dried at 40 °C and 100 °C while there was a significant difference in the value of crude lipid and moisture content of the fresh sample in relation to the values obtained from the samples dried at the various drying methods. Total ash content was lowest in the fresh sample. Table 3c also revealed that among the drying methods used, the shade-dried samples showed the highest value of 63.44±0.06 % for carbohydrate, 4.54±0.02 % for crude lipid, 11.35±0.03 % for moisture content and 7.11±0.02 % for total ash compared to the other drying methods while the fresh sample had lowest values of carbohydrate (27.43±0.05 %) and total ash (2.67±0.02 %). The results on the proximate analysis for *A. muricata* is as shown in Table 3c.

The result for proximate content of the leaves of *Azadirachta indica* is shown in Table 3d. It was observed that shade-dried samples showed the highest percentage for the carbohydrate, and total ash while it showed the lowest value (6.06±0.04 %) for crude fibre content. The control sample had lowest value of carbohydrate (30.17±0.04 %) but the highest values of crude lipid (25.81±0.05 %) and moisture content (45.01±0.04 %). The sample dried at 100°C had the lowest value of crude lipid (0.34±0.02 %) while the sample dried under the sun had the lowest value of moisture content (2.26±0.02 %) which is a significant difference from the value of the fresh (control) sample.

Table 3a: Proximate content of *Citrus latifolia* leaves at different drying conditions

Drying methods	Proximate content (%)					
	Carbohydrate	Crude protein	Crude lipid	Moisture content	Total ash	Crude fibre
Fresh sample	28.08±0.06	4.21±0.02	33.70±0.03	54.35±0.03	2.82±0.03	8.20±0.02
Dried @ 100°C	49.14±0.39	15.72±0.03	0.60±0.01	2.41±0.02	2.41±0.15	29.81±0.15
Dried @ 40°C	53.23±0.03	19.15±0.02	0.65±0.15	2.64±0.01	2.51±0.01	21.73±0.01
Sun dry	50.47±0.01	16.90±0.15	0.87±0.01	2.7±0.01	2.44±0.02	26.02±0.15
Shade dry	68.74±0.25	4.42±0.04	4.44±0.04	9.82±0.09	4.97±0.02	7.61±0.10

Table 3b: Proximate content of Cymbopogon citratus leaves at different drying conditions

Drying methods	Proximate content (%)					
	Carbohydrate	Crude protein	Crude lipid	Moisture content	Total ash	Crude fibre
Fresh sample	23.20±0.04	5.09±0.02	37.82±0.03	49.73±0.04	4.68±0.02	7.84±0.07
Dried @ 100°C	47.25±0.02	16.48±0.02	1.28±0.15	2.21±0.02	4.24±0.01	28.43±0.02
Dried @ 40°C	44.04±0.02	17.32±0.15	1.25±0.01	2.16±0.02	4.58±0.01	30.58±0.02
Sun dry	48.58±0.02	15.64±0.15	1.26±0.02	2.21±0.02	4.48±0.02	27.58±0.02
Shade dry	57.84±0.12	6.15±0.04	6.61±0.03	12.08±0.03	8.25±0.01	9.06±0.06

Table 3c: Proximate content of *Annona muricata* leaves at different drying conditions

Drying methods	Proximate content (%)					
	Carbohydrate	Crude protein	Crude lipid	Moisture content	Total ash	Crude fibre
Fresh sample	27.43±0.05	8.92±0.02	29.86±0.02	55.83±0.06	2.67±0.02	7.65±0.02
Dried @ 100°C	48.44±0.53	14.83±0.02	1.31±0.04	2.49±0.08	4.17±0.03	29.03±0.33
Dried @ 40°C	47.65±0.10	14.80±0.04	1.15±0.31	2.34±0.02	4.89±0.03	29.21±0.13
Sun dry	50.80±0.32	14.96±1.46	1.22±0.03	2.33±0.08	3.14±0.04	28.69±0.67
Shade dry	63.44±0.06	7.29±0.03	4.54±0.02	11.35±0.03	7.11±0.02	6.29±0.03

Table 3d: Proximate content of *Azadirachta indica* leaves at different drying conditions

Drying methods	Proximate content (%)					
	Carbohydrate	Crude protein	Crude lipid	Moisture content	Total ash	Crude fibre
Fresh sample	30.17±0.04	2.99±0.01	25.81±0.05	45.01±0.04	3.00±0.07	6.63±0.03
Dried @ 100°C	48.47±0.21	11.40±0.63	0.34±0.02	2.64±0.57	2.01±0.09	35.52±0.24
Dried @ 40°C	54.32±0.22	11.38±0.51	0.52±0.04	2.66±0.56	3.12±0.05	28.38±0.10
Sun dry	46.71±0.23	11.61±0.53	0.36±0.01	2.26±0.02	2.15±0.05	36.95±0.17
Shade dry	72.53±0.02	3.26±0.06	3.41±0.01	9.45±0.03	5.29±0.01	6.06±0.04

Values are means±SD for 3 determinations

Discussion

Drying is the most common, fundamental and structural process for post-harvest preservation of medicinal plants because it allows for quick conservation of the medicinal qualities of the plant materials in uncomplicated ways. Various studies such as Veeresham, (2012), Sofowora *et al.* (2013) and Boy *et al.* (2018) revealed that phytochemicals, especially those obtained from medicinal plants, have been used to help mankind sustain her health since the dawn of medicine. Phytochemical and proximate analyses conducted on the leaves of *Annona muricata*, *Azadirachta indica, Citrus latifolia* and *Cymbopogon citratus* dried using various drying methods of shade, sun and oven (40 °C and 100°C) revealed the presence of phytochemicals such as alkaloid, tannins, flavonoids, saponins, phenols, steroids and terpenoids in varying proportions. All the phytochemical contents analyzed were found to be present in *A. indica* leaves at the different drying methods except for saponin which was not observed in 40 °C oven-dried and sun-dried samples and anthraquinone which was only noticed in the fresh sample. This could probably be due to the effect of the drying method on the functional group linked to the phytochemicals in this plant as drying causes some physiochemical and bioactive changes in the plant. This correlates with the findings of Ujah *et al.* (2021) who observed these phytochemicals in the leaves of *A. indica.* Although, their experiment only involved air drying at room temperature. These phytochemicals were also present in *Annona muricata* leaves. Agreeing with the findings of Usunobun *et al.* (2014) on phytochemical screening of *A. muricata* leaves.

Anthraquinone was only detected in the fresh and shade dried samples of *C. latifolia* and *C. citratus* at a negligible amount while only noticed in the fresh sample of *A. indica.* This could be traced to a couple of factors like the drying process. Being an aromatic compound, the heat from the oven drying and sun-drying processes could have caused some substitution reactions which could affect the accumulation of anthraquinone in leaves. Also, Abo and Adeyemi (2002) studies on *Cassia podocarpa* revealed that seasonal changes could affect the accumulation of anthraquinone in the leaves of plants.

The quantity of phytochemical compounds detected in the sampled leaves under the different drying methods showed that the drying method can alter the composition and structure of the compounds. As secondary metabolites, most phytochemicals like saponins can undergo structural and chemical changes when subjected to conditions such as heat from oven and detachment from parent source which could result in alteration in concentration, production and retention of such phytochemicals in the plant's organ. This was also asserted in the studies of Rocha *et al.* (2011), Lusia *et al.* (2015) and Santana *et al.* (2018). Alkaloids were observed to be highest in the shade-dried sample of *A. indica*. However, there was no significant difference ($p<0.05$) in the quantity of alkaloid in the *A. muricata, C. citratus* and *C. latifolia* samples. The values of the phenolic and tannin contents were highest in all the fresh samples and significant decline were observed along the drying gradient. This is

in contrast to the report of Roshanak *et al.* (2016) who reported highest total phenol content at 60 ! oven-dried *Camellia sinensis* leaves sample but also noted that the phenolic content decreased in higher temperature (80 ! and 100 !). This is however, similar to the observation in the present study as noted in the *A. muricata, C. latifolia* and *A. indica* samples. Perhaps, the phenol and tannin contents present in the sampled plants are hydrolysable and thus might have vapourized with moisture during drying. Tannin is a secondary metabolite belonging to the phenol compound group. The results also correlated the submission of Tran *et al.* (2020) who noted a decline in the total phenolic content in *A. muricata* after drying. Similarly, Sejali and Anuar (2011) posited that medicinal quality of plant parts is affected due to the thermal decomposition of the active ingredients during the drying process. As they observed that the phenolic content of shade dried *A. indica* leaves was higher than that obtained from the 45 ! or 70 ! oven-dried leaves. Fernandes *et al.* (2018) also reported lower value of hydrolysate tannin in hot-air dried *Centaurea cyanus* petals. The drying methods seemed not to have affected the values of flavonoids and terpenoids in all the plant samples. Flavonoids and phenolics are free radical scavengers that prevent oxidative cell damage, and have strong anticancer activities (Pourmorad *et al*., 2006 and Ugwu *et al*., 2013) and they might induce mechanism that affect cancer cells and inhibit tumor invasion (Husain *et al*., 1987). These activities could be attributed to their ability to neutralize and quench free radicals (Ugwu *et al*., 2013). Tannins are known to be useful for the prevention of cancer as well as treatment of inflamed or ulcerated tissues. (Okwu and Emineke, 2006; Adegboye *et al*., 2008). Drying causes the volatile profile of essential oil to change due to the formation of secondary aroma compounds such as alcohols, aldehydes, peroxide and ketones (Turek and Stintzing, 2013).

In the proximate analysis, the leaves of the shade dried plant samples had the highest value of ash content while there were no significance differences among the samples dried under the sun and in the oven. This is similar to the report of Santana *et al.* (2018) where they reported a variation in the ash content of *Ilex guayusa* leaves due to the drying methods. The ash content is a reflection of the mineral contents preserved in the plants' leaves. According to Afolabi *et al.* (2005) plants with more than 10-18 % ash are likely contaminated with increasing amount of soil, excess ash content and can have negative effect on lactation for example in cattle. Vermani *et al.* (2010) also asserted that the amount and composition of ash remaining after combustion of plant material varies considerably according to the part of the plant, age, treatment etc. The value of ash content was highest in the *C. citratus* leaves (8.25±0.01 %). This connotes that the leaves of this plant may have more mineral contents than the leaves of the other sampled plants, as ash content was taken as a rough measure of the mineral contents of food materials as submitted by Anwar *et al.* (2008). The moisture content of all the plant samples were low (<5.00 %) across the drying methods except for the shade dried samples. Moisture is the water content that remains inside the cell, once the extracellular water clears away by drying. Thus, moisture is of great importance because high amounts indicate poor drying process which can lead to deterioration of the plant material by the growth of microorganisms and biotransformation of secondary metabolites of the plant materials. The pharmacopoeias recommend values of 8 and 14% depending on the vegetable organ studied (Santana *et al.*, 2018) was however not exceeded in any of the studied samples under the various drying methods. This goes to show that the dried samples had significant difference in moisture content compared to the fresh samples. There was however no significant difference in the values obtained amongst the oven dried and sun-dried samples. This can imply that the drying methods were appropriate for drying the leaves under study. The crude fibre content of all sampled plants significantly ($p<0.05$) increased in the

oven-dried and sun-dried samples. This could be as a result of the effect of heat from the oven and from the sun on the leaves. High temperature is known to cause a breakdown of the glycosidic bonds of polysaccharides leading to the release of oligosaccharides and an increase in the quantity of fibre plant organs. This correlates with the study of Hassan *et al.* (2007) where they reported an increase in crude fibre content with drying methods on the leaves of *Gynandropsis gynandra.* It was also observed that the crude protein content also increased in the oven-dried and sun-dried samples. This results tallies with the assertion of Naikwade (2015) on leafy vegetables. However, this is contrary to Morris *et al.* (2004) who reported losses of macronutrients especially protein due to application of heat and Hassan *et al.* (2007) study where three drying methods of solar, sun and oven were used to analyze the nutritional and non-nutritional values of *Gynandropsis gynandra* leaves and reported that intensity of heat applied due to efficiency of the dryer commensurate with the decrease in protein content.

When compared with the sun-dried samples the oven-dried (40 ! and 100 !) samples had no significant impact on the phytochemical contents of the sampled plants. The samples dried in the oven temperature showed increase in alkaloid, flavonoid and saponin while there were decrease in tannin, phenol in comparison with the shade dried and fresh samples. The proximate contents did not differ significantly along the drying methods. Overall, drying can alter the chemical structure of medicinal plants.

Conclusion

Drying of medicinal plants can increase the shelf-life as this limit deteriorating enzymatic reactions and keeps microorganisms aby. However, the method of dehydrating medicinal plants must be considered with respect to species, plant part, method, duration and purpose of drying. As the choice of the appropriate drying temperature remains a central economic and ecological criterion in the drying of medicinal plants.

References

Abo, K. and Adeyemi, A. (2002). Seasonal accumulation of anthraquinones in leaves of cultivated *Cassia podocarpa* Guill et Perr. *African Journal of Medicine and Medical Sciences*, 31; 171-173. PMID: 12518917.

Adegboye, M. F., Akinpelu, D. A. and Okoh, A. (2008). The bioactive and phytochemical properties of *Garcinia kola* (Heckel) seed extract on some pathogens. *African Journal of Biotechnology*, 7(21); 3934 3938.

Afolabi, F. and Afolabi, O. J. (2013). Phytochemicals constituents of some medicinal plants in South west, Nigeria. *Journal of Applied Chemistry*, 4(1); 76-78. DIO:10.9790/5736-0417678

Afolabi, G., Oluwade, A. and Tunde, O. (2005). Estimation of proximate and mineral composition of some tropical Crops. *African Agricultural Journal*, 21; 103-109.

Annamalai, A., Ponmari, G., Sathishkumar, R. and Lakshmi, P.T.V. (2011). Effect of drying treatment on the contents of antioxidants in *Cardiospermum halicacabum* Linn. *International Journal of Pharma and Bio Sciences*, 2; 304-313.

AOAC (2012). International. *Official methods of analysis of AOAC International.* 19th ed. Gaithersburg, MD, USA: AOAC International.

Auwal, M. S., Saka, S., Mairiga, I. A., Sanda, K. A., Shuaibu, A. and Ibrahim, A. (2014). Preliminary phytochemical and elemental analysis of aqueous and fractionated pod extracts of *Acacia nilotica* (Thorn mimosa). *Veterinary Research Forum,* 5(2); 95-100.

Anwar, F., Rehana, N., Bhange, R. M. I., Ashfat, S., Farah, N. T. and Felix, A. (2008). Physicochemical characteristic of citrus seeds as seed oils from Pakistan. *Journal of American Oil Chemists Society,* 7; 112-119.

Boy, H.I.A., Rutilla, A.J.H., Santos, K.A.,

Ty, A.M.T., Yu, A.I., Mahboob, T. Tangpoong, J. and Nissapatorn, V. (2018). Recommended medicinal plants as source of natural products: A Review, *Digital Chinese Medicine*, 1(2); 131-142. https://doi.org/10.1016/S2589-3777(19)30018-7.

Calderón-Oliver, M. and Ponce-Alquicira, E. (2018). Fruits: A source of polyphenols and health benefits. In: *Handbook of Food Bioengineering*. Grumezescu, A.M. and Holban, A.M. (Eds.). Academic Press, 189-228. ISBN 9780128115183.

Dhani, R. (2012). Extraction and chemical investigation of leaves of *Pterospermum acerifolium*. *International Journal of Pharmaceutical Research and Bio-Science*, 1(6); 299-314. http://www.ijprbs.com/issuedocs/2012/...

Diaz-Maroto, M. C., Perez-Coello, M. S. and Cabezudo, M. D. (2002). Effect of different drying methods on the volatile components of parsley (*Patroselinum crispum* L.). *European Food Research and Technology*, 215; 227-230. https://doi.org/10.1007/s00217-002-0529-7

Edoga, H.O., Okwu, D.E. and Mbaebie, B.O. (2005). Phytochemicals constituents of some Nigerian medicinal plants. *African Journal Biotechnology*, 4(7); 685-688. **DOI:** 10.5897/AJB2005.000-3127

Fernandes, L., Casal, S., Pereira, J.A., Saraiva, J.A. and Ramalhosa, E. (2018). Effects of different drying methods on the bioactive compounds and antioxidant properties of edible Centaurea (*Centaurea cyanus*) petals. *Brazilian Journal of Food Technology Campinas*, v. 21, e2017211, https://doi.org/10.1590/1981-6723.21117243

Freeman, B.C. and Beattie, G.A. (2008). An overview of plant defenses against pathogens and herbivores. *The Plant Health Instructor*. DOI: 10.1094/PHI-I-2008-0226-01

Hassan, S.W., Umar, R.A., Maishanu, H.M., Matazu, I.K., Faruk, U.Z. and Sani, A.A. (2007). The effect of drying method on the nutrients and non-nutrients composition of leaves of *Gynandropsis gynandra* (Capparaceae). *Asian Journal of Biochemistry*, 2; 349-353. **DOI:** 10.3923/ajb.2007.349.353

Hossain, M. A., AL-Raqmi, K. A. S., Al-Mijizy, Z. H., Weli, A. M., and Al-Riyami, Q. (2013). Study of total phenol, flavonoids contents and phytochemical screening of various leaves crude extracts of locally grown *Thymus vulgaris*. *Asian Pacific journal of tropical biomedicine*, 3(9); 705-710. DOI: 10.1016/S2221-1691(13)60142-2

Husain, S.R., Cillard, J. and Cillard, P. (1987). Hydroxyl radical scavenging activity of flavonoids. *Journal of Phytochemistry*, 26(9); 2489-2491. https://doi.org/10.1016/S0031-9422(00)83860-1

Kutama, R.M., Abdulkadri, S., Kwalli, S.A. and Chiroma, B. (2018). Phytochemical compositions in some Nigerian medicinal plants and their pharmacological properties: A review. *International Journal of Anastasia and Clinical Medicine*, 6(1); 15-25. doi: 10.11648/j.ja.20180601.14

Loi, M., Paciolla, C., Logrieco, A.F. and Mulè, G. (2020). Plant bioactive compounds in pre- and postharvest management for aflatoxins reduction. *Frontiers in Microbiology*, 11; 243. doi: 10.3389/fmicb.2020.00243

Lusia, B.M., Hasmadi, M., Zaleha, A.Z. and Mohd Fadzelly, A.B. (2015). Effect of different drying methods on phytochemicals and antioxidant properties of unfermented and fermented teas from Sabah Snake Grass (*Clinacanthus nutans* Lind.) leaves. *International Food Research Journal*, 22(2); 661-670. *http://www.ifrj.upm.edu.my*

Maisarah, A. M., Asmah, R., and Fauziah, O. (2014). Proximate analysis, antioxidant and antiproliferative activities of different parts of *Carica papaya*. *Journal of Tissue Science & Engineering*, *5*(1), 1. DOI: 10.4172/

2157-7552.1000133

Mendoza, N. and Silva, E. M. E. (2018). Introduction to phytochemicals: Secondary metabolites from plants with active principles for pharmacological importance. In: Asao, T. and Asaduzzaman, M. (Eds.). *Phytochemicals - Source of Antioxidants and Role in Disease Prevention.* IntechOpen. https://doi.org/10.5772/intechopen.78226

Moghadamtousi, S.Z., Goh, B.H., Chan, C.K., Shabab, T. and Kadir, H.A. (2013). Biological activities and phytochemicals of *Swietenia macrophylla* king. *Molecules*, 18; 10465-83. DOI: 10.3390/molecules180910465

Morris, A., Barnett, A. and Burrows, O.J. (2004). Effect of processing on nutrient content of foods. *Cambridge Archaeological Journal,* 37(3); 160-164. http://amro.who.int/ English/CFNI/ cfni-caj37No304-art-3.pdf) 15.07.2010.

Muller, J. and Heindl, A. (2006). Drying of medicinal plants. In: *Medicinal and Aromatic Plants*. Bogers, R.J., Craker, L.E. and Lange, D. (Eds.). Springer. 237-252.

Naikwade, P.V. (2015). Effect of drying methods on nutritional value of some vegetables. *Bioscience Discovery*, 6(1-I) Special. http:// biosciencediscovery.com

Offor, C.E. (2014). Comparative chemical analyses of *Vernonia amygdalina* and *Azadirachta indica* leaves. IOSR *Journal of Pharmacy and Biological Sciences (IOSR-JPBS.),* 9; 73-77. e-ISSN: 2278-3008, www.iosrjournals.org.

Okwu, D. E. and Emenike I. N. (2006). Evaluation of the phytonutrients and vitamin contents of Citrus fruits. *International Journal of Molecular Medical and Advance Science*, 2; 1-6. https://medwelljournals.com/abstract/?doi=ijmmas.2006.1.6

Orphanides, A., Goulas, V. and Gekas, V. (2016). Drying technologies: Vehicle to high-quality herbs. *Food Engineering Reviews*, 8(2); 164–180. doi: 10.1007/s12393-015-9128-9.

Poós, T. and Varju, E. (2017). Drying characteristics of medicinal plants. *International Review of Applied Sciences and Engineering,* 8(1); 83-91. DOI: 10.1556/1848.2017.8.1.12

Pourmorad, F., Hosseininelir, S. J., and Shahabimajd, N. (2006). Antioxidant activity, phenol and flavonoid content of some selected Iraninan medicinal plants. *African Journal of Biotechnology*. 5; 1142-1145. http:// www.academicjournals.org/AJB

Rocha, R. P., Melo, E. C. and Radünz L. L. (2011). Influence of drying process on the quality of medicinal plants: A review. *Journal of Medicinal Plants Research*, 5(33); 7076-7084, DOI: 10.5897/JMPRx11.001

Roshanak, S., Rahimmalek, M. & Goli, S.A.H. (2016). Evaluation of seven different drying treatments in respect to total flavonoid, phenolic, vitamin C content, chlorophyll, antioxidant activity and color of green tea (*Camellia sinensis or C. assamica*) leaves. *Journal of Food Science and Technology*, 53(1); 721-729. DOI 10.1007/s13197-015-2030-x

Santana, P.M., Quijano-Avilés, M., Chóez-Guaranda, I., Lucas, A.B., Espinoza, R.V., Martínez, D., Camacho, C. and Martínez, M.M. (2018). Effect of drying methods on physical and chemical properties of *Ilex guayusa* leaves. *Revista Facultad Nacional de Agronomía Medellín,* 71(3); 8617-8622. doi: 10.15446/rfnam.v71n3.71667

Sejali, S. N. F. and Anuar, M.S. (2011). Effect of Drying Methods on Phenolic Contents of Neem (*Azadirachta indica)* Leaf Powder. J*ournal of Herbs, Spices and Medicinal Plants,* 17(2); 119-131 https://doi.org/10.1080/10496475.2011.584293

Sofowora, A., Ogunbodede, E., and Onayade, A. (2013). The role and place of medicinal plants in the strategies for disease prevention. *African Journal of*

Traditional, Complementary, and Alternative Medicines, 10(5); 210-229. https://doi.org/10.4314/ajtcam.v10i5.2

Thiex, N. (2009). Evaluation of analytical methods for the determination of moisture, crude protein, crude fat, and crude fiber in distillers dried grains with solubles. *Journal of AOAC International*, 92(1); 61-73. https://doi.org/10.1093/jaoac/92.1.61

Tran, N.Y.T., Nhan, N.P.T., Thanh, V.T., Nguyen, D.V., Thinh, P.V., Vy, T.A., Lam, T.D. and Truc, T.T. (2020). Effects of drying conditions on total phenolic content and other parameters of soursop jelly (*Annona muricata* L.). *IOP Conference Series: Materials Science and Engineering*, 736. 022064**DOI** 10.1088/1757-899X/736/2/022064

Turek, C. and Stintzing, F. C. (2013). Stability of essential oils: A review. *Comprehensive Reviews in Food Science and Food Safety,* 12(1); 40–53. doi: 10.1111/1541-4337.12006.

Ugwu, O.P.C., Nwodo, O.F.C., Joshua, P.E., Bawa, A., Ossai, E.C. and Odo, C.E. (2013). Phytochemical and acute toxicity studies of *Moringa oleifera* ethanol leaf extract. *International Journal of Life Sciences Biotechnology and Pharmaceutical Research*, 2(2); 66-71.

Ujah, I.I., Nsude, C.A., Ani, O.N., Alozieuwa, U.B., Okpako, I.O. and Okwor, A.E. (2021). Phytochemicals of neem plant (*Azadirachta indica*) explains its use in traditional medicine and pest control. *GSC Biological and Pharmaceutical Sciences*, 14(02); 165–171 **DOI:** 10.30574/gscbps.2021.14.2.0394

Ukoha, P. O., Cemaluk, E. A., Nnamdi, O. L. and Madus, E. P. (2011). Tannins and other phytochemical of the *Samanaea saman* pods and their antimicrobial activities. *African Journal of Pure and Applied Chemistry*, 5(8); 237-244. https://doi.org/10.5897/AJPAC.9000161

Usunobun, U., Okolie, N. P., Anyanwu, O. G. and Adegbegi, A.J. (2014). Phytochemical screening and proximate composition of *Annona muricata* leaves. *European Journal of Botany, Plant Science and Phytology*, 2(1); 18-28. www.eajournals.org

Veeresham, C. (2012). Natural products derived from plants as a source of drugs. *Journal of Advanced Pharmaceutical Technology and Research*, 3(4); 200-201. https://doi.org/10.4103/2231-4040.104709

Vermani, A., Navneet, Prabhat and Chauhan, A. (2010). Physico-chemical analysis of ash of some medicinal plants growing in Uttarakhand, India. *Nature and Science*, 8(6); 88-91.

World Health Organization (WHO) (2007). Resolution-Promotion and Development of Training and Research in Traditional Medicine. WHO Document No: 30-49.